APPENDIX B
LEAP: AN END-USE ACCOUNTING AND MODELING SYSTEM

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LEAP represents a relatively easy to use and flexible accounting and modeling framework developed by the Stockholm Environment Institute - Boston Center at the Tellus Institute. (SEI, 1993a; SEI, 1993b) As a "bottom-up", end-use modeling system, LEAP's principal elements are the energy and technology characteristics of end-use sectors and supply sources. The end-use approach, embodied in LEAP, enables the incorporation and simulation of several important factors that can have significant effects on future GHG emissions. Such factors include technological improvements and transitions, the limits imposed by the saturation of energy-intensive activities, and structural shifts among economic sectors and subsectors.

LEAP contains a full energy system accounting framework, which enables consideration of both demand and supply-side technologies and accounts for total system impacts. For example, a reduction in electricity requirements will lead to a decrease in the operating costs of the electric plants operating on the margin, and a decrease in the import or local production and distribution of the fuels used for electricity generation. With links to the Environmental Data Base, LEAP can track the pollution resulting from each stage of the fuel chain, including the reduction in GHG emissions from extraction, processing, distribution, and combustion activities that might result from the more efficient use of electricity or other fuels.

LEAP possesses several specific characteristics, summarized in Box B1, that make it suitable for mitigation scenario analysis in many countries. It has been widely used in developing and industrialized countries since 1980 for a variety of integrated energy-environment analyses. In recent years, applications have included several GHG mitigation studies.

This appendix presents an overview of the LEAP system and its capabilities. A description of how LEAP can be applied to GHG mitigation assessment is given in Appendix 4 to the Technical Report to Chapter IV.B of the IPCC Second Assessment Report.

Box B1 Key Characteristics of LEAP

- Comprehensive, integrated system covering both energy demand-side and supply-side mitigation options and providing cost and emissions analysis.
- Model-building system and accounting framework rather than a fixed model.
- Flexible and expandable data structures; can be used under conditions of limited data.
- Choice of modeling methodologies, e.g., end-use and/or econometric demand relationships; load curve dispatch or fixed plant shares for electric system.
- Associated Environmental Data Base contains extensive emission factor data.
- Easy-to-use, menu-driven interface and straightforward data entry screens.
- Integrated context-sensitive help and full documentation; flexible reporting system including built-in graphics.
- Runs on standard PCs under MS-DOS (requires 640K RAM and 6 MB free hard disk space).
- Off-the-shelf training exercises; on-site training available.
- Used in numerous developing and industrialized countries over the past 15 years.

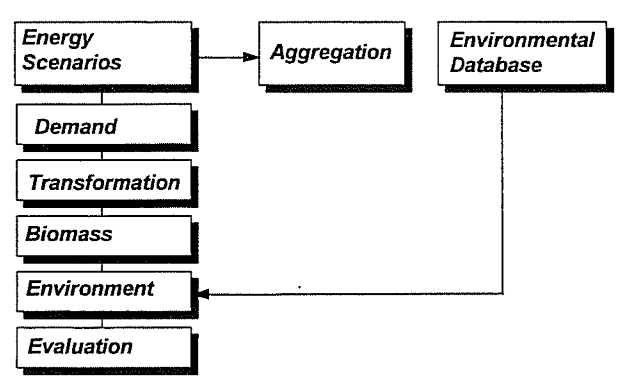
LEAP APPLICATIONS

LEAP was initially developed as part of the Kenya Fuelwood Project, one of the first major integrated energy planning exercises conducted in a developing country.[1] Since that time, LEAP has been used in over 30 developing and industrialized countries for a wide range of tasks, including, most recently, GHG mitigation analysis. Government ministries and planning units, such as those in Tanzania, Zambia and Zimbabwe have used LEAP to build institutional capacity for energy planning, and assist in the formulation of energy master plans (Mrindoko and Lazarus, 1992). Some LEAP applications, such as in the Philippines, have emphasized decentralized rural energy planning (van der Werf, 1992). In other applications, planners have used LEAP to evaluate biomass demand and supply policies, as in the state of Minas Gerais in Brazil (Ackerman and Fernandes de Almeida, 1990). In Hungary, LEAP was used to compare coal and nuclear-based energy futures, and is now being used to consider a wider range of supply options. Researchers in India used LEAP to look at options for minimizing air pollution from the transport sector in Delhi (Bose and Mackenzie, 1993). LEAP has also provided the analytical framework for two global energy and climate change studies (Sinyak and Nagano, 1992; Lazarus et al., 1993).

Most recently, LEAP has been used directly for mitigation scenario analyses. As part of the UNEP Greenhouse Gas Abatement Costing Studies project (UNEP 1994a), it was used by analysts in Senegal and Venezuela. It has also been used for greenhouse gas-related scenario analyses in the U.S. and Costa Rica (UCS et al., 1991; von Hippel and Granda, 1992).

LEAP STRUCTURE AND DESIGN

Figure B1 LEAP Program Structure



The structure of LEAP is presented schematically in Figure B1. LEAP consists of three blocks of programs: Energy Scenarios, Aggregation, and the Environmental Data Base (EDB). Four of the Energy Scenario programs address the main components of a mitigation analysis: energy demand analysis (Demand), energy conversion and resource assessment (Transformation), emissions estimation (Environment), and the comparison of scenarios in terms of costs and physical impacts (Evaluation). These four programs and EDB are described below. The optional Biomass program is available to assess the relationship between biomass energy demands, supplies, and land use changes. For a more detailed description of LEAP structure and capabilities see SEI-B (1993a & 1993b).

The LEAP system is *demand driven.* That is, demand requirements drive the calculations

[1] Details of these and other early LEAP studies can be found in volumes 1,2 and 9 of *Energy, Environment and Development.* (Beijer Institute and Scandinavian Institute of African Studies, 1984-1986)

of the Transformation program, and the results of the Transformation program, in turn, drive the calculations of the Biomass, Environment, and Evaluation programs. Supply constraints and feedbacks are managed by the analyst through modifications of the demand scenarios.

The LEAP Demand program provides a disaggregated, end-use approach to the analysis of energy requirements. Rather than a rigid pre-set model of energy demands, the Demand program is a flexible *model-building* tool that enables the construction of a wide range of models to reflect local conditions. The user can create a four-level "branch structure" to represent a desired model of energy use, as illustrated in Figure B-2.[2] This branch structure can be relatively simple or more elaborate, depending on data availability and the analyst's modeling preferences.

When creating baseline and alternative scenarios, the future values for each branch -- activity levels, percentage shares, and energy intensities -- are determined. For example a projection might be based on changes in sectoral driving variables (e.g., growth in numbers of households), subsector breakdowns (e.g., income distribution), end-uses (e.g., space cooling), and device usage (e.g., the mix of more and less efficient air conditioners and their levels of usage).

The **Demand program** contains several options for projecting future changes in activity levels and energy intensities: interpolation/extrapolation of values determined exogenously (i.e. outside of LEAP); econometric relationships; or user-specified growth rates. Exogenous values can be incorporated from other analyses, using various forecasting methods -- such as expert judgment, trending analysis, or content analysis. For instance, projections of value added or GDP for the chemicals industry could be taken from a macroeconomic analysis of sectoral performance or from a government production target. As with all LEAP programs, the Demand program contains a flexible report writing and graphing facility that enables the detailed review and presentation of scenario results in different formats and energy units, and at different levels of disaggregation.

The **Transformation Program** simulates energy supply and conversion processes and enables the assessment of primary resource requirements, needs for facility expansion, and import and export levels. Like the Demand program, it is designed as a model-building tool rather than a fixed model. The user can tailor the design of the supply system simulation to match the resources and facilities in a given region, and their general operational rules and characteristics.

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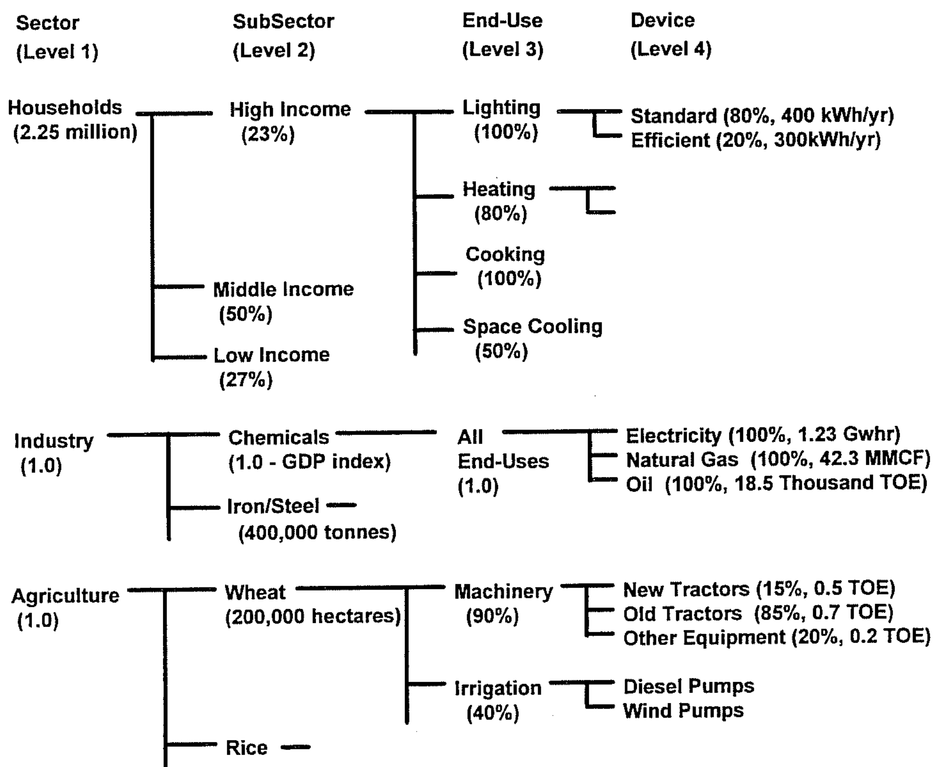
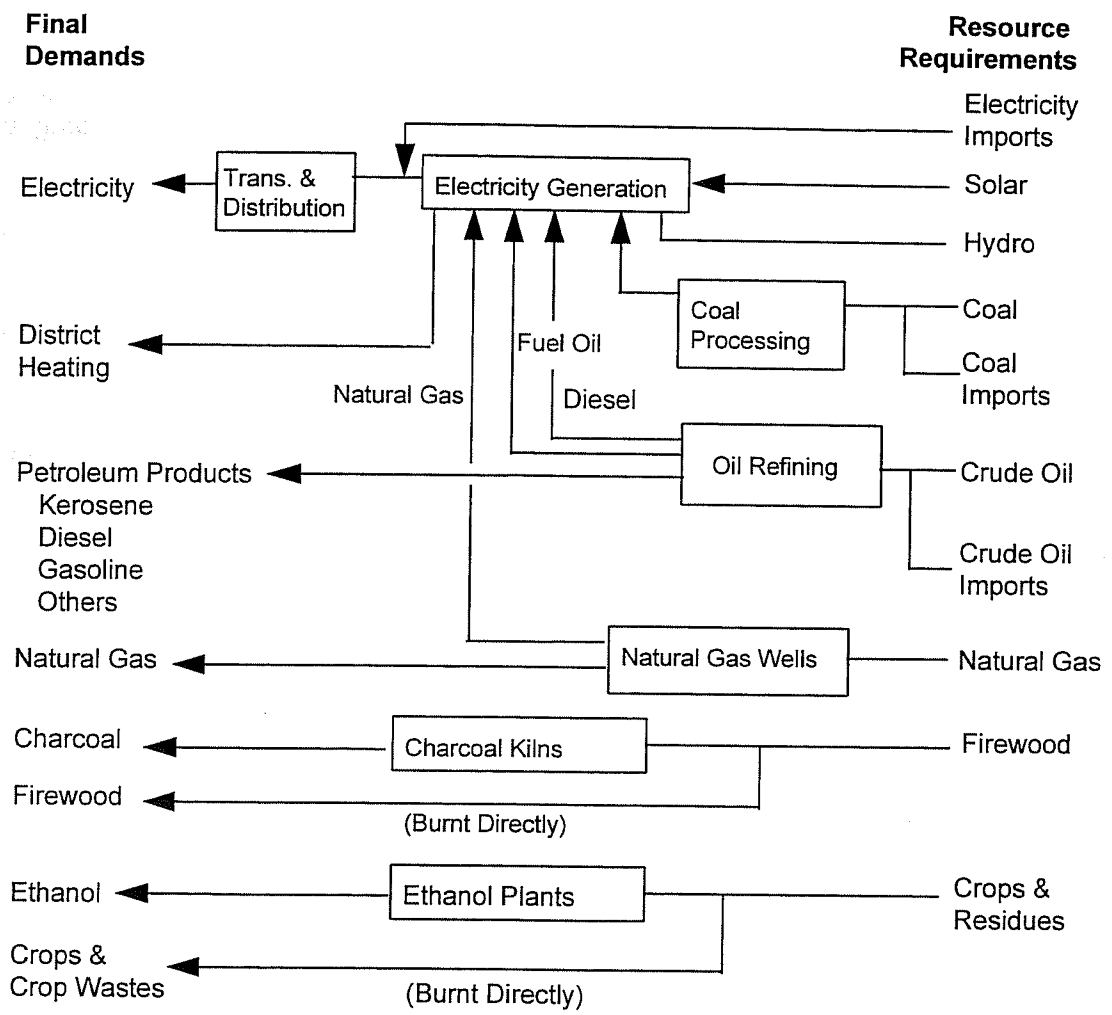
[2] The four level titles in the LEAP Demand program – *Sector, Subsector, End-Use*, and *Device* -- are merely for guidance, and the user need not abide by them. For instance, under subsector, a given user may enter end-uses, crop types, housing types, income categories, or whatever type of disaggregation deemed appropriate for the analysis.

Figure B-2 Schematic of a Sample LEAP Demand Structure



Each sector, subsector, end-use, or device is referred to as a "branch". From right to left, each branch refers to the branch of the preceding level. In the example shown, there are 2.25 million households in the sample area, 23% of these are in the high income group, all of these households have lighting, and 80% use standard (incandescent) electric lighting at an average consumption of 400 kWh/year per household.

Figure B-3 Schematic of Sample LEAP Transformation Structure



The boxes above refer to LEAP Transformation "modules". Modules can be added, removed, or modified to suit local conditions.

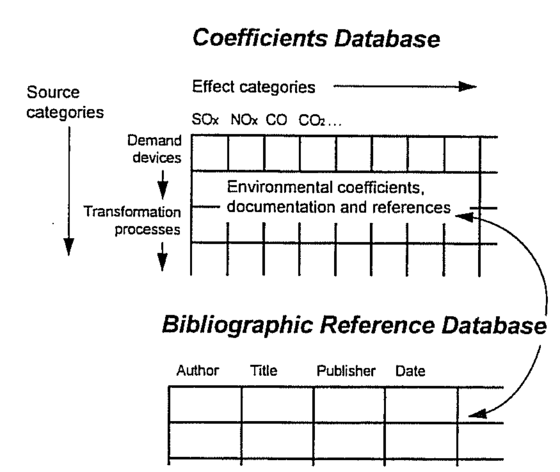
The Transformation system is defined at two levels of detail: the *module* level, which represents energy industries or sectors such as grid electricity generation, industrial cogeneration, oil refining, district heating, or charcoal production; and the more detailed *process* level, which describes the cost and performance characteristics of individual energy conversion and production technologies such as electric plants, oil refineries, or coal mines. The analyst has a variety of options for simulating the operation of energy production and conversion systems. For instance, the electric facilities can be dispatched to meet an annual load curve or refineries can be specified to operate at maximum production levels with the export of excess (and import of unmet) petroleum product demands. Other options include alternative policies for specifying the availability of fuel imports, for dealing with shortfalls in production, for setting priorities between domestic consumption and export targets, for handling surplus production of energy products, for specifying waste energy recovery, and for modeling cogeneration.

In addition to modules describing energy production and conversion activities, the Transformation program also allows the user to define the available base year stocks and additions to reserves of primary indigenous fossil fuel resources. The calculations in the Transformation system track the depletion of reserves over the analysis period. The Transformation program produces a wide variety of reports and graphs, including energy balances.

The **Environment program** calculates the environmental emissions and on-site health and safety impacts associated with a particular energy scenario. These estimates are based on emission coefficients contained in EDB (the Environmental Data Base) that are matched with specific sectors, end-uses, and/or technologies in the Demand and Transformation programs of LEAP. LEAP can optionally calculate the emissions from the full fuel chain, providing that the proper Transformation modules for the fuel chain are specified in the LEAP data set. As an example of fuel chain emissions, the consumption of electricity might result in GHG emissions from natural gas combustion at a generating facility. In addition, there may be releases of methane in the transmission of natural gas from the gas production site to the power plant, as well as emissions of methane and carbon dioxide at the gas production site itself. These potentially important effects can be accounted for, if the distribution and production of natural gas and appropriate emission factors are specified in the Transformation program and EDB, respectively.

The **Environmental Data Base (EDB)** contains a wide range of technology-specific emission factors for major greenhouse gases. In addition, users can add data appropriate to local facilities or to specific studies.[3] To date, EDB data have been gathered from over 60 references. EDB contains emission factors for both modern technologies (e.g. electric generation facilities, refineries, boilers) and traditional devices used in many developing countries (e.g. biomass stoves). The coverage of EDB is currently being expanded as part of the UNEP/SEI Fuel Cycle Analysis project. In addition, specific country studies continue to contribute to the database.

Figure B-4 EDB Program Structure



The **Evaluation program** compares the physical impacts, the economic costs and benefits, and the comparative environmental emissions of one scenario relative to another, e.g. a mitigation scenario relative to the baseline scenario. Capital and operating and maintenance

[3] Global climate change is but one of many important energy-related environmental problems. LEAP and EDB can also be used to examine other environmental consequences that may be of more immediate concern in many areas, such as the emissions of local air pollutants.

costs are entered in the Demand, Transformation and Biomass programs, and together with per-unit resource costs and optional environmental externality costs they are used in conjunction with the physical results of the other LEAP programs to calculate the comparative costs of different energy-environment scenarios. Reports of the physical, energy, and cost differences between scenarios can be displayed for the whole energy sector, or for selected elements of the energy system, in nominal, real, or discounted terms.

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